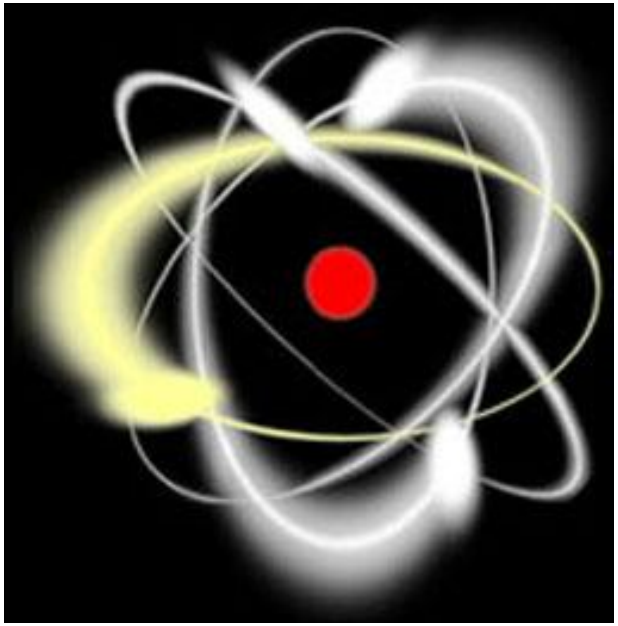
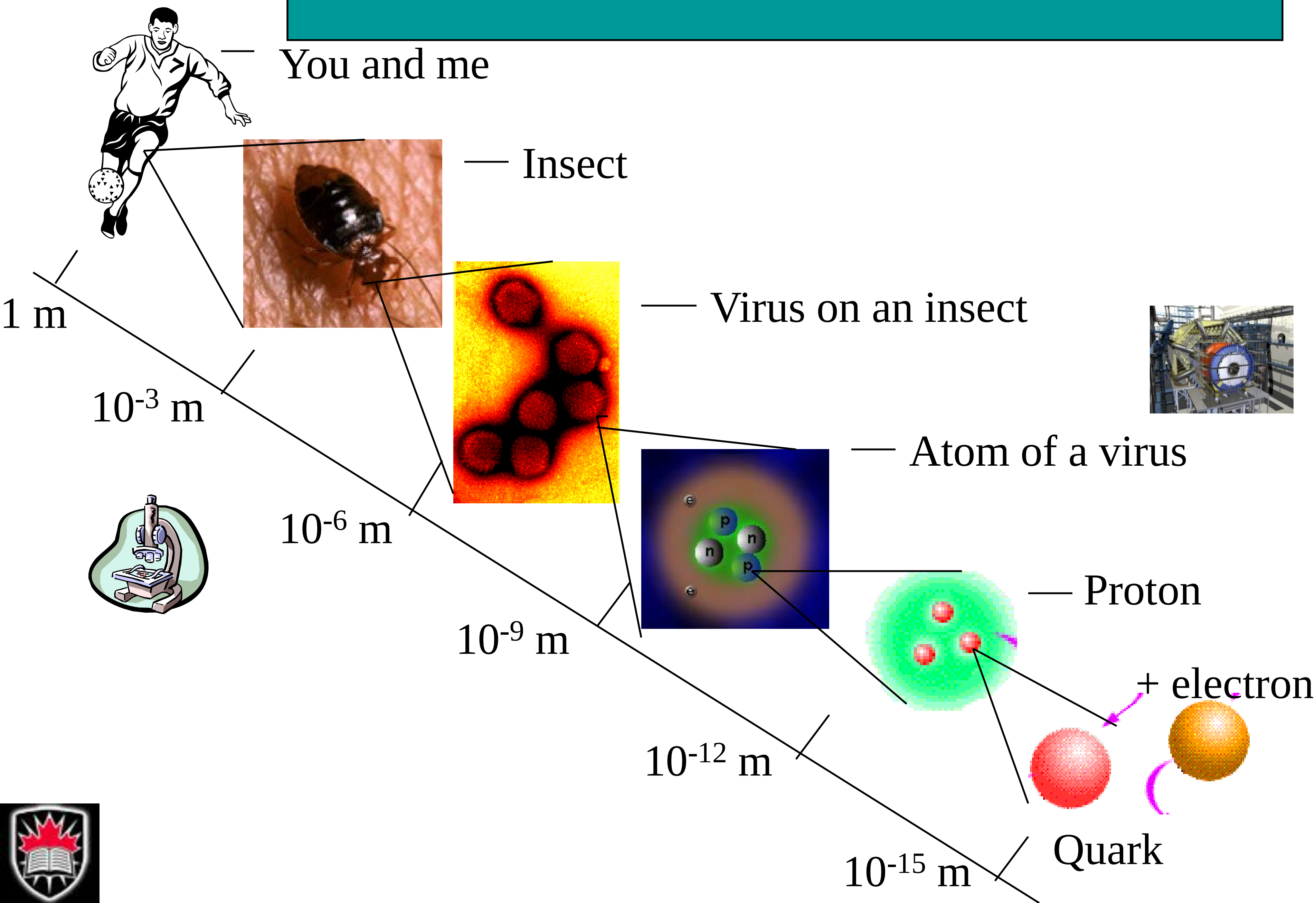
Measurement of Charge to Mass Ratio For an Electron



(Thomson's Experiment)

The scale of the subatomic world



The Electron:

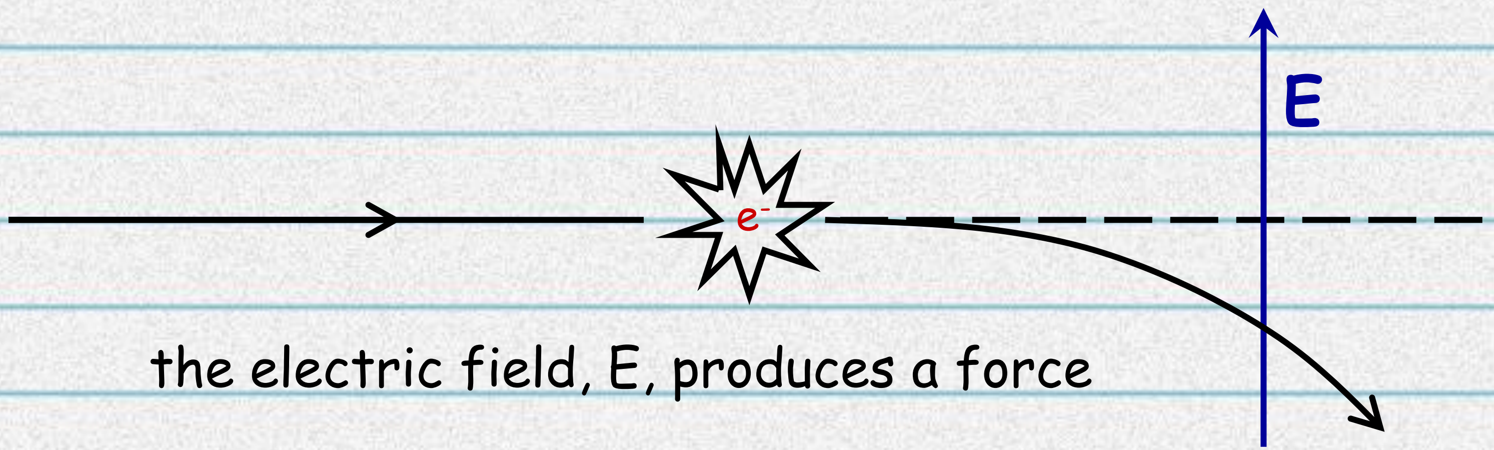
- is an elementary particle: smallest speck of matter
- is normally found in the immediate vicinity of a nucleus, forming an atom
  - Mass (m_e): 9.11×10^{-31} kg
  - Charge (e): 1.6×10^{-19} C (C = Coulombs)

- Charge is found by Millikan's Oil Drop experiment

- So, if we can find e/m_e, we can determine m_e
- In 1897, J.J. Thomson found this value
  - Ratio (e/m_e): -1.76×10^{11} C/kg
- Your Job: try to repeat that measurement today

Forces affecting the electron:

1. The electric field:



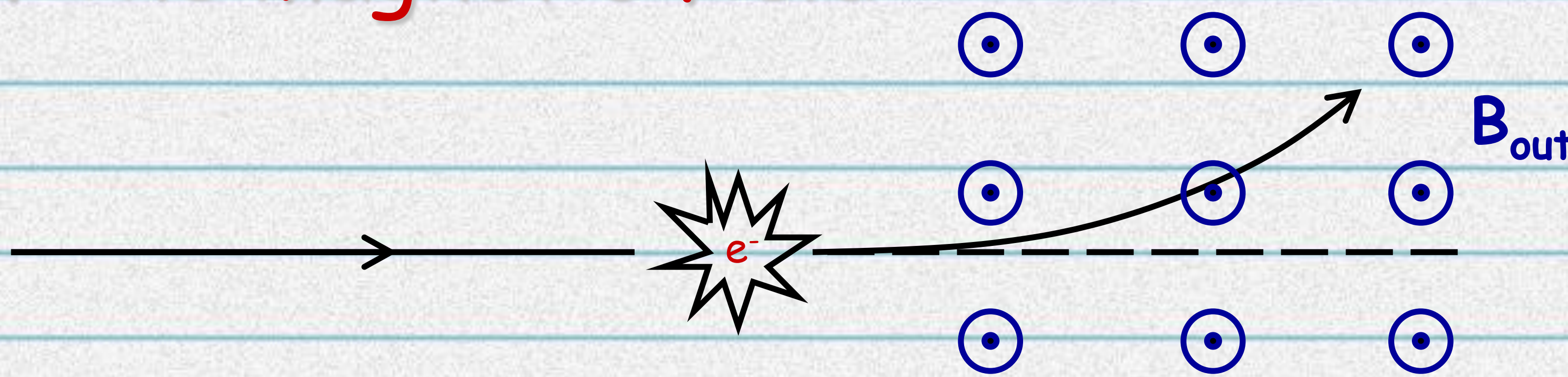
the electric field, E, produces a force

$F_E = q \cdot E$ (q = e, the charge of the electron)

The electric field, E, always points in the direction that a +ve charge would move if it were within the field.

Forces affecting the electron:

2. The magnetic field:



The magnetic field (B_{out}) produces a force:

$F_B = B_{out} \cdot e \cdot v$ (v is the velocity of the electron)

This force is perpendicular to both B_{out} and v.

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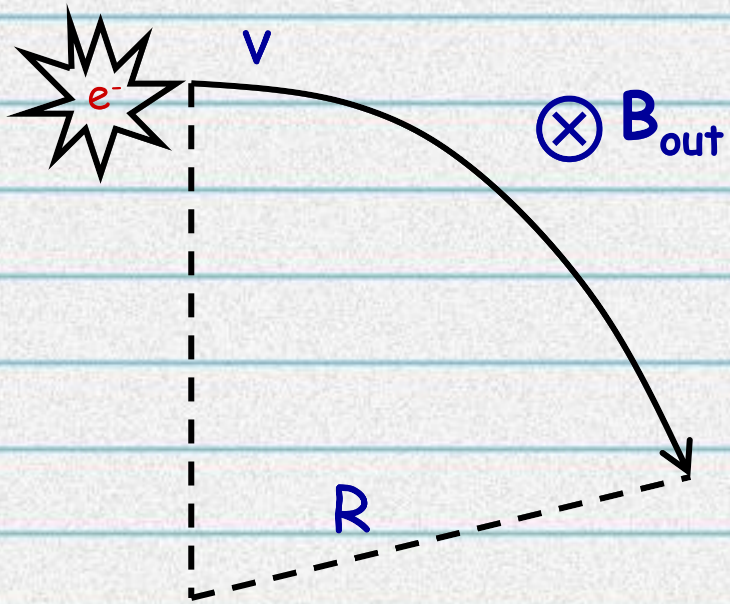
Finding e/m:

- Electrons move in circles in magnetic fields
- This motion produces a centripetal force

$$F = \frac{mv^2}{R}$$



- We can equate this to F_B:

$$Bev = \frac{mv^2}{R}$$

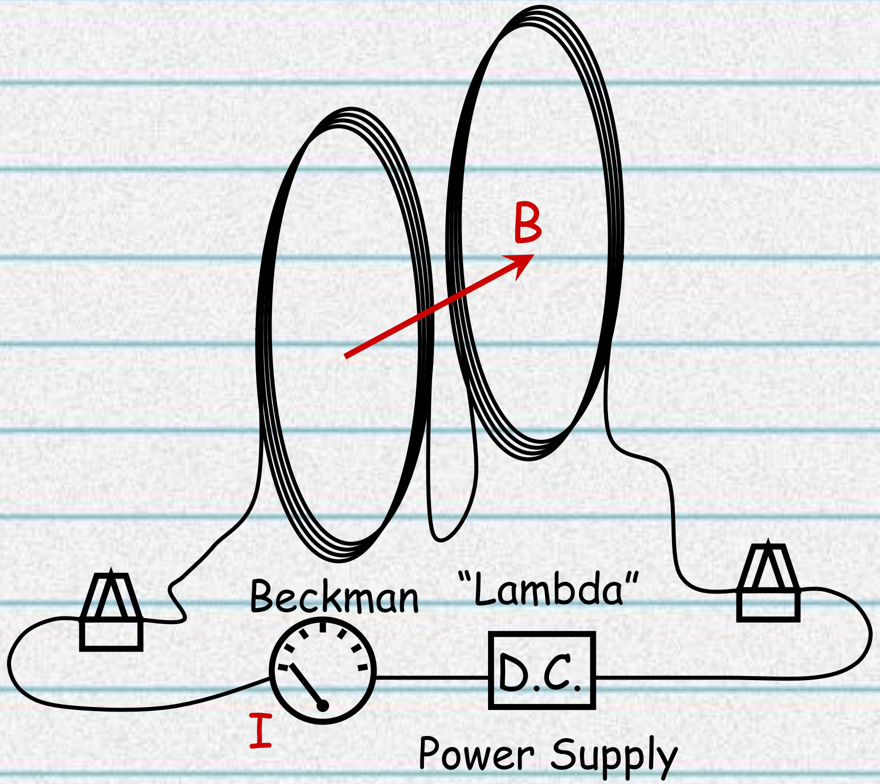
- Re-arranging:

$$\frac{e}{m} = \frac{v}{BR}$$

- *Thus, to find e/m we need to know 3 things: the magnetic field, B, the radius of curvature, R, and the velocity of the electrons, v.*

Finding the magnetic field, B:

- "Helmholtz" coil arrangement delivers uniform magnetic field



- B depends on current, and is calibrated to be:

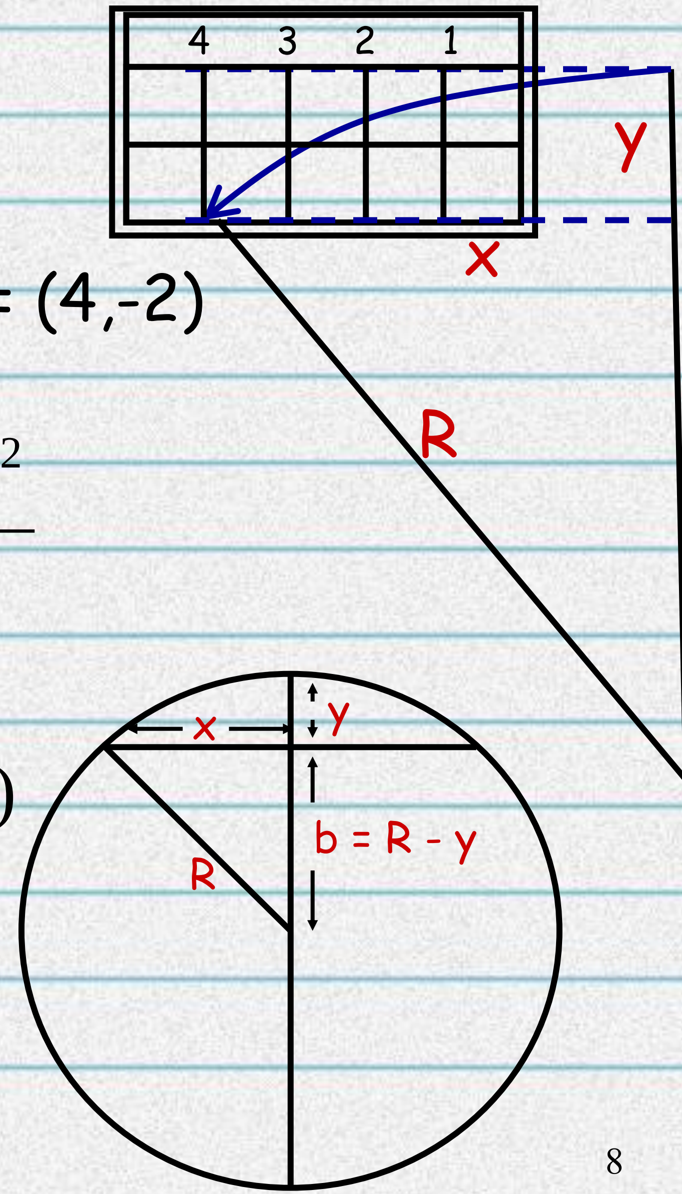
$$B = I \times 4.23 \times 10^{-3}\ \mathrm{Wb\ m^{-2}}$$

(I measured in Amps)

Determine the radius, R:

- Measure y - deflection at a distance, x, from the exit of the electron

(x,y) = (4,-2)



- Given (x,y) - find R

$$R = \frac{x^2 + y^2}{2y}$$

- To prove this, try Pythagoras:

$$(R - y)^2 = b^2 = (R^2 - x^2)$$

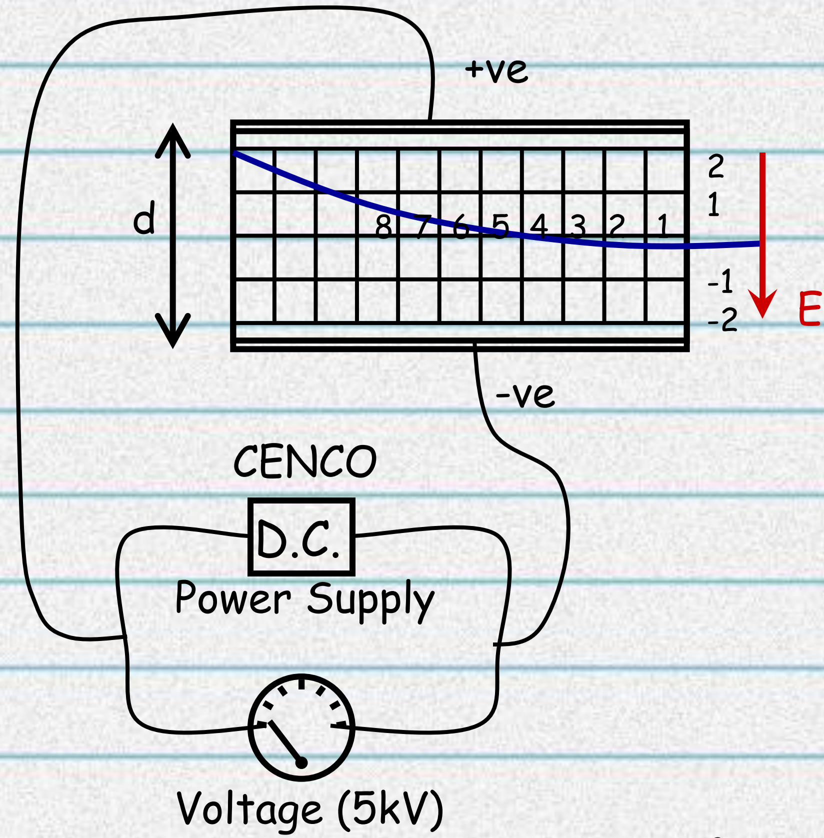
$$R^2 - 2Ry + y^2 = R^2 - x^2$$

$$R = \frac{x^2 + y^2}{2y}$$

Determine the velocity, v:

- Now switch on the Electric Field
  - Use it to cancel the effects of the B field

$$E = \frac{V}{d} = \frac{V}{0.052}$$



- Use the Electric field to cancel the deflection at the x value where the magnetic deflection was measured

$$Ee = Bev$$

$$v = \frac{E}{B} \quad (\mathrm{m/s})$$

Procedure:

- Plug in transformer for cathode heater supply
- Switch on CENCO D.C. supply to accelerate electrons down the tube and onto the screen

  set to ~ 2400 V
- There should now be a blue trace on the screen
- Switch on Beckman meter and Lambda power supply unit connected to coils

  set to ~ 0.2 A
- Determine B

Procedure:

- Measure (x,y):

  determine R

- Switch on second CENCO DC supply connected to electrodes on top of mica screen

  set to ~ 1.5 kV

- Adjust to cancel deflection:

  determine v

- Fill in worksheet and calculate e/m
- Switch off all power supplies

Thomson's e/m experiment

		Your Measurements	Units	Calculated quantities		Units
Determining the	x		metres	$R = (x^2 + y^2)/2y$		metres
Radius(R) of the track	y		metres			
Determining the	I		amps	$B = 4.23x10^{-3}\ I$		Tesla
Magnetic Field (B)						
Determining the	V		volts	$E = V/0.052$		volts/metre
Electric Field (E)						
Determining the				$v = E/B$		metres/sec
electron's velocity(v)						